Drill-stem tests, production testing, and well-log analysis confirm the presence of up to 400 net ft (122 m) of gas-productive stratigraphic traps in the sandstones.

The results of fracture stimulation treatments confirm that with presently available technology, economically useful stimulation can be performed on sandstone zones more than 20 ft (6 m) thick with average permeabilities exceeding 0.03 md.

No present technique for analyzing well-log suites currently in use is consistently successful in designating zones which meet these minimum stimulation requirements. Special efforts must be made to evolve techniques for this purpose. In the interim, a renewed emphasis on drilling and completion methods which make possible natural flows of commercial volumes from thick gas saturated intervals will complement the search for the most efficient means to accelerate deliverabilities from the Upper Cretaceous-Paleocene rocks.

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Alvord Valley, Oregon Geothermal Investigation

The Alvord Valley in southeastern Oregon may have geothermal power potential. Underground temperatures in the five hot springs in the valley have been estimated to be in excess of 140°C through the use of various chemical geothermometers. The valley is bounded on both sides by north trending basin-and-range-type normal faults exposing as much as 5,500 ft (1,676 m) of Miocene and younger volcanic rocks.

The sulfates of the five Alvord area hot springs and associated local evaporites were sampled and analyzed for their sulfur isotopic values. Preliminary results indicate that the sulfate in the hot springs is leached from the playa evaporite deposits through which the water is circulating and that there is apparently no component of magmatic sulfur in the water. This agrees with both deuterium-hydrogen and 180/160 isotope data for the same springs which indicate that the water is meteoric in origin. Four of the five springs contain anomalous amounts of boron thought by some workers to be characteristic of waters of volcanic origin. However, analysis of volcanic and older metavolcanic rocks exposed on the valley sides show that the boron probably originates from leaching of volcanic rocks present at the base of the section. Thus anomalous amounts of boron also do not necessarily indicate the presence of magmatic water.

Gravity profiles were run across four of the five areas containing springs to help delineate the structural configuration of the valley and faults through which hot spring waters are circulating. These structure profiles together with sulfur isotope and other geochemical information indicate that the water in the Alvord Valley geothermal system originates as runoff from the mountains on each side of the valley. The water then circulates down through faults and fractures in the mountains and reappears at the surface along faults at the margins or in the middle of the valley. The origin of the heat for this system is either: (1) rapid circulation of water in an area with a high geothermal gradient; (2) an active deep-seated heat source such as a magma chamber or solid igneous rocks in the process of cooling; or (3) frictional heating due to rapid circulation. The fact that no component of magmatic water was found in the hot springs suggests that the first possibility is the most likely.

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Cedar Creek Anticline, Past and Present

More than 240 million bbl of oil has been produced from Mississippian, Silurian, and Ordovician carbonate reservoirs in the crestal part of the Cedar Creek anticline of eastern Montana, North Dakota, and South Dakota. This pronounced surface fold, more than 120 mi (160 km) long and encompassing approximately 2,000 sq mi (5,200 sq km), developed through a complex geologic history of recurrent tectonic movements along a northwest-southeast-striking fault zone on the southwest flank of the Williston basin.

Although shallow gas production from Upper Cretaceous sandstones was established in 1912, Paleozoic oil first was discovered in the mid-1930s with short-lived production from Ordovician and Mississippian carbonate rocks in the Little Beaver area. The existence of giant reserves was not indicated until the discovery of Glendive and Pine fields in 1951. Drilling subsequently delineated a nearly continuous producing trend on the crestal part of the anticline as well as several small accumulations on the near east flank. Ultimate primary and supplemental phases of production probably will exceed 315 million bbl of oil and 60 Bcf of solution gas, more than 94 percent expected from the Silurian and Ordovician reservoirs.

Subsurface data from more than 950 exploratory and development wells drilled during the past 25 years document four major periods of tectonism from early Paleozoic through mid-Tertiary time.

1. Post-Silurian–pre-Middle Devonian: uplift and probable fault movement accompanied initial north and east tilting of the main Cedar Creek block.
2. Late Devonian–pre-Mississippian: fault movement and uplift created a broad northwest-southeast-striking anticlinal feature and significant structural closures.
3. Late Mississippian (Chester) through Triassic: periods of subsidence occurred along the crestal block with relative down-to-the-east normal fault movement along part of the ancestral master and subsidiary faults.
4. Post-Paleocene: uplift of the Cedar Creek block was accompanied by major flexuring, strong asymmetric drape folding, minor fault adjustment, and significant increase of northwest plunge along the crestal part: several subsidiary structures semiparallel to Cedar Creek formed southwest of the main trend. The entire area subsequently was uplifted during the epeirogenic phases of the mid-Tertiary in the northern Rocky Mountain region.

Although favorable traps of major size existed in the ancestral Cedar Creek region during Paleozoic and Mesozoic periods, geochemical and LOM studies indicate oil migration from organic-rich Ordovician and Mississippian source rock sequences in the basin on the east did not begin until the late Late Cretaceous. Present structural closures appear only partly to control accumulation, as production extends over major areas of the anticline exhibiting only axial plunge. Known limits of productivity generally align more closely with mappable